Examining Lake Michigan Spring Euphotic Depth (Zeu) Anomalies

utilizing 10 years of MODIS-Aqua data at 4 kilometer resolution

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The Great Lakes are a striking and easily recognized target for remote sensing

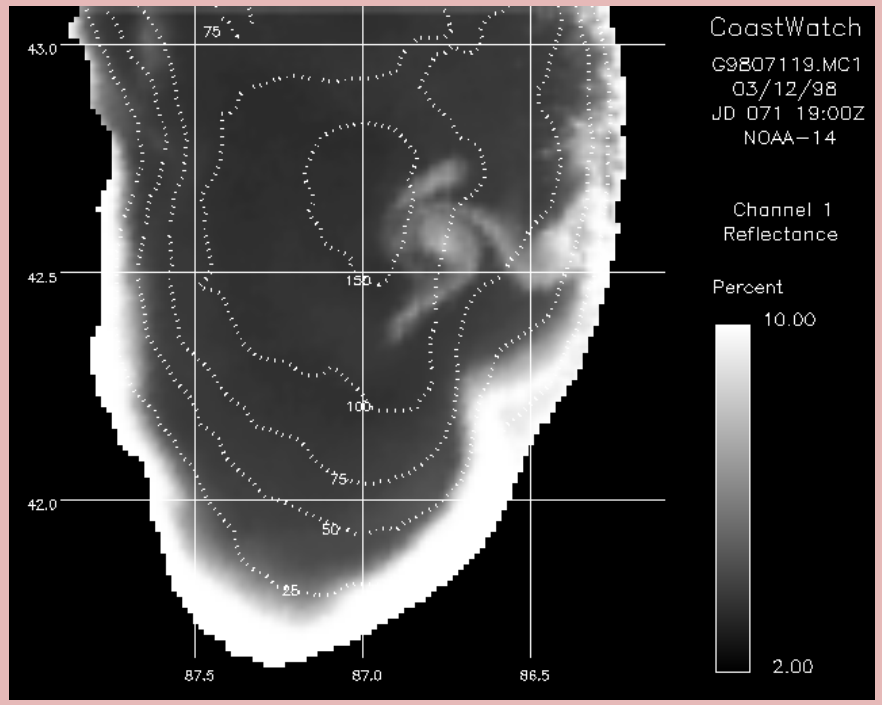
But until recently, remotely-sensed “ocean” optical products have not been as accurate for large lakes.

Euphotic depth (Zeu) is a more robust product for lakes than chlorophyll *a* concentration.

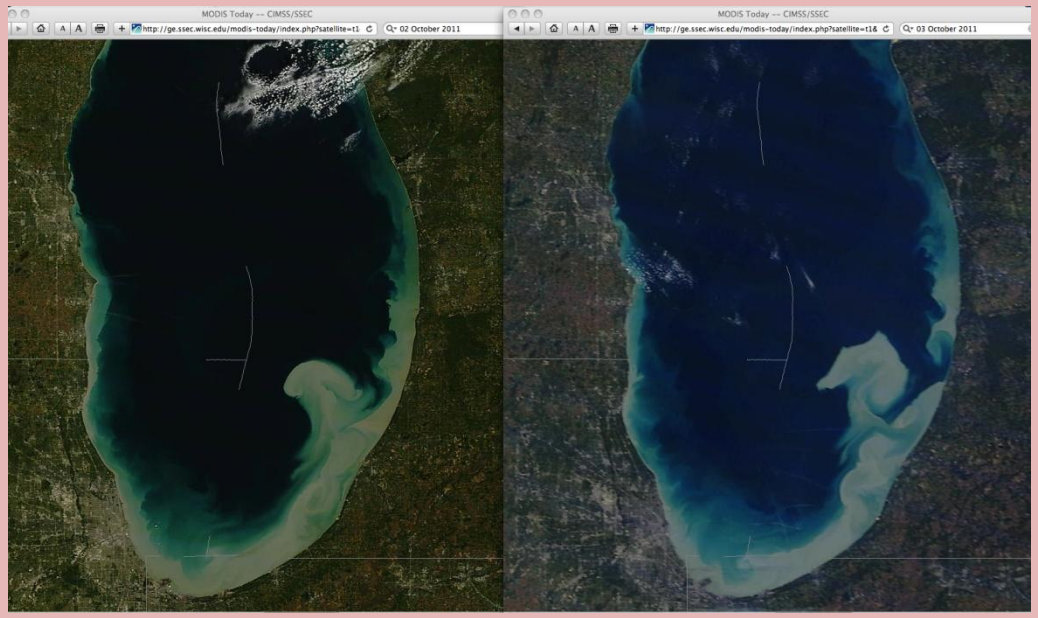
Euphotic depth is the depth at which the light intensity is 1% of its intensity at the surface of the water column.

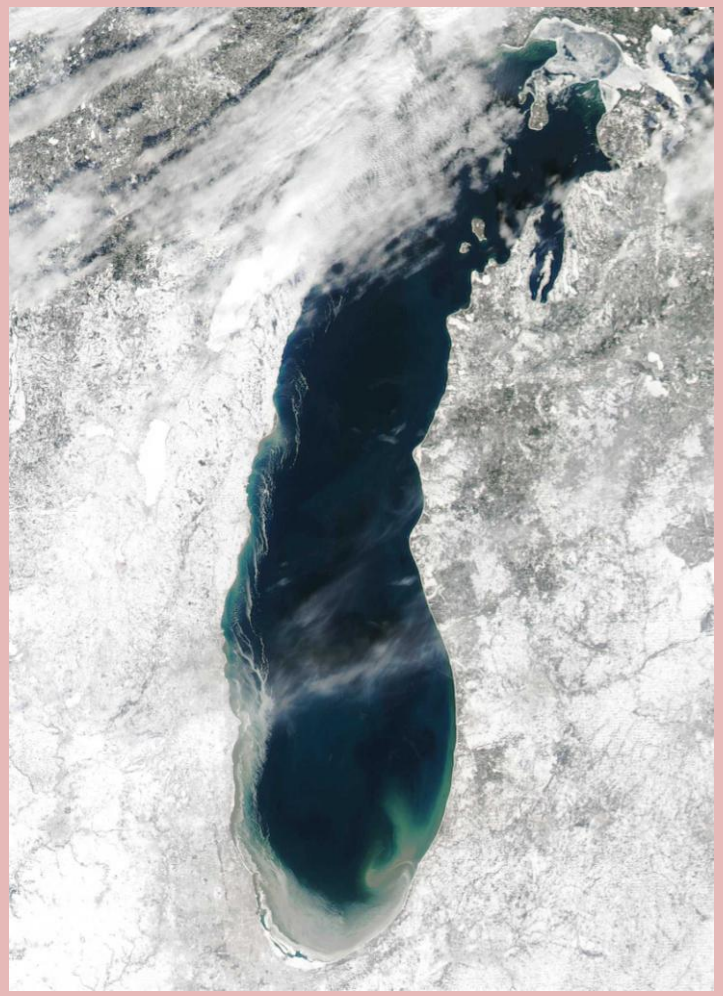
It is an excellent indicator of the presence of suspended sediments or phytoplankton blooms.

The initiation of nearly-continuous remote-sensing observations of the United States' Great Lakes revealed the semi-regular occurrence of a resuspended sediment turbidity feature in southern Lake Michigan. This feature was more commonly observed in spring when northerly winds dominate, causing increased wave action in the southern end of the lake and a wind-induced coastal current regime. The sediment resuspension feature was studied during the Episodic Events in the Great Lakes Experiment (EEGLE) in the 1998-2000 time period.



NOAA AVHRR reflectance data, March 12, 1998

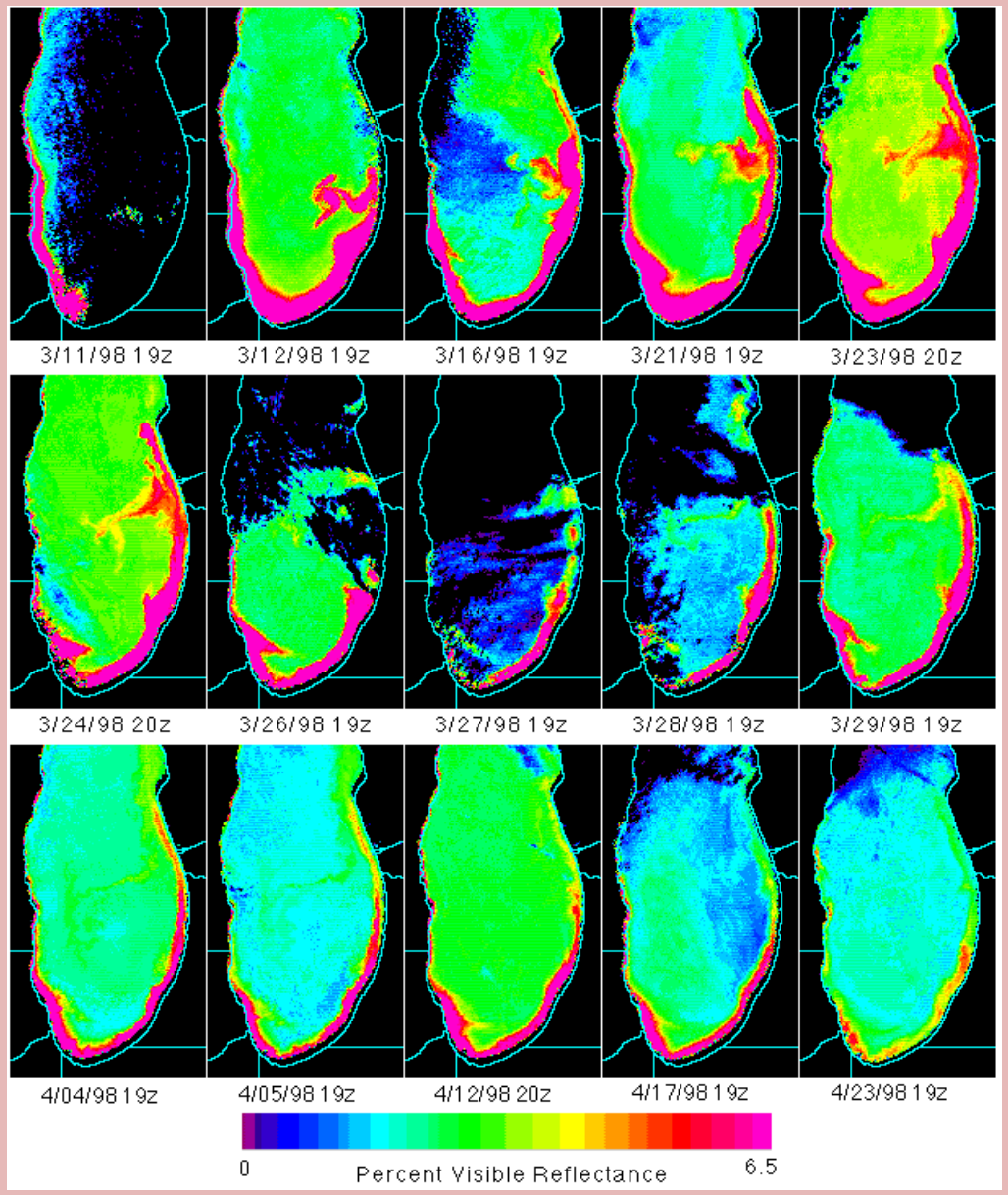




Elevated turbidity in the southern part of the lake can appear at other times, such as October (above), or February (right).

BRRR!

Chicago is called “the Windy City” for a reason!



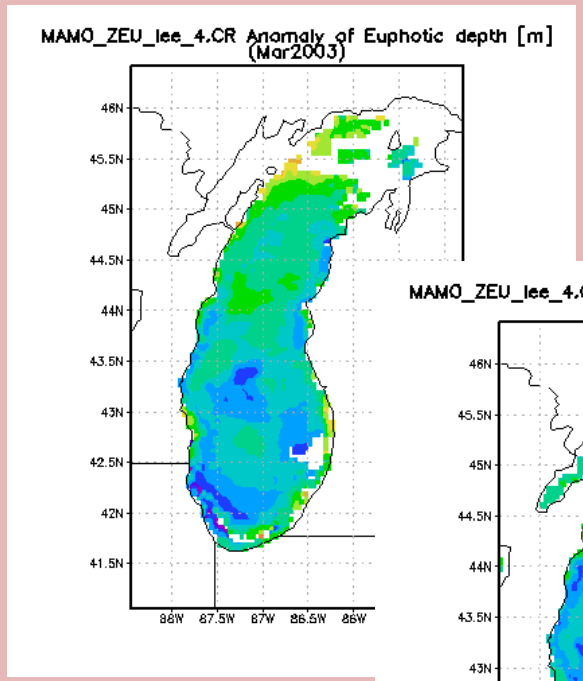
The sequence of reflectance images at right shows the development and evolution of the turbidity plume in March and April 1998.

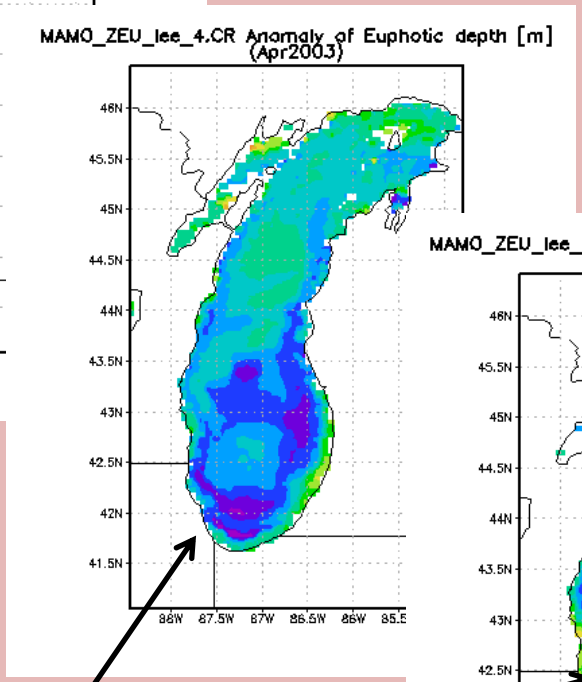
Despite the fact that elevated turbidity in the southern end of Lake Michigan can occur at any time, it has been thought to be primarily a spring occurrence.

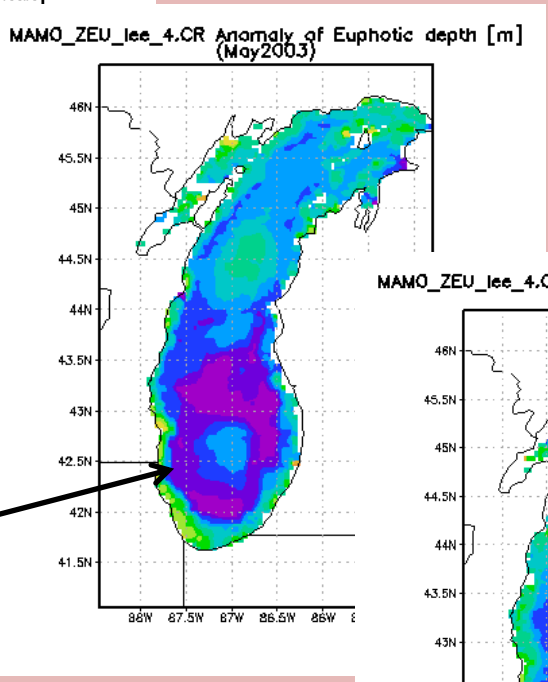
Each of the next slides shows images of the euphotic depth anomaly for the months of March, April, May, and June, for each year in the period 2003-2012.

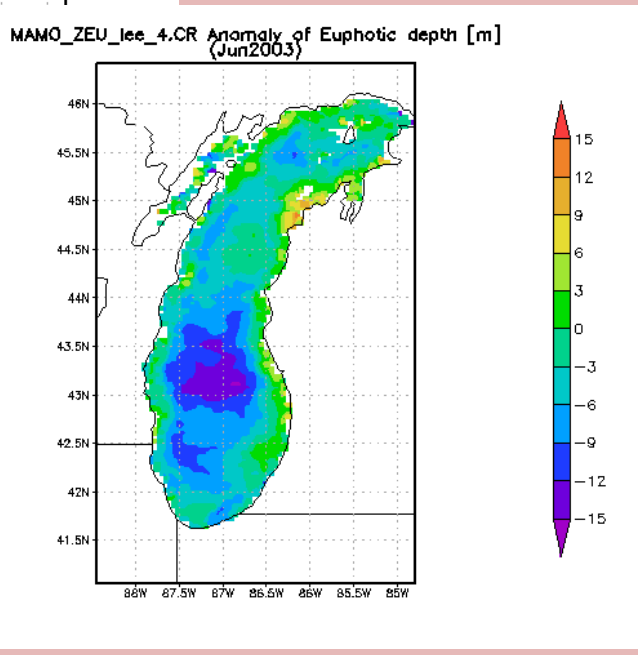
The monthly anomalies are calculated from the 10-year MODIS-Aqua euphotic depth climatology, which is now available in Giovanni.

Several other ocean optical parameters now have climatologies and anomaly analysis capability in Giovanni for the first time.





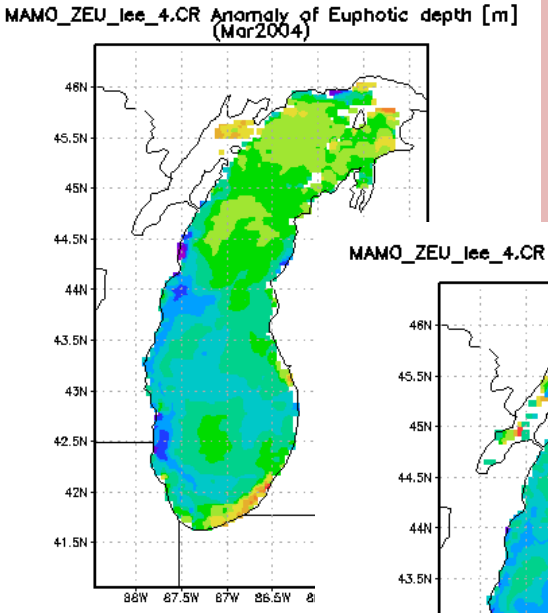


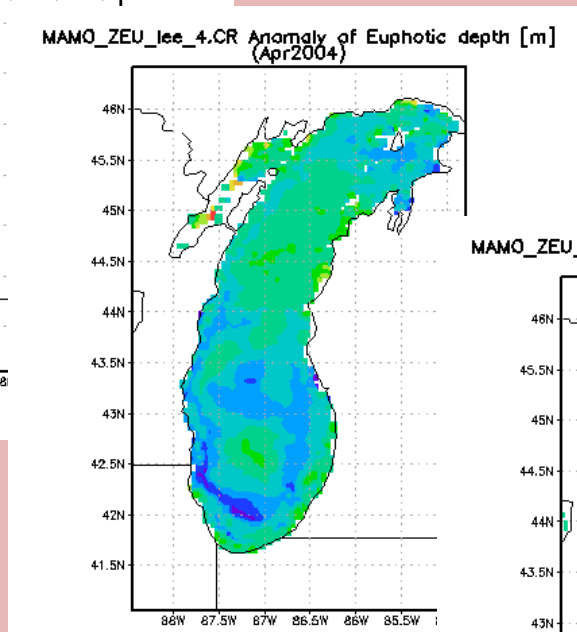


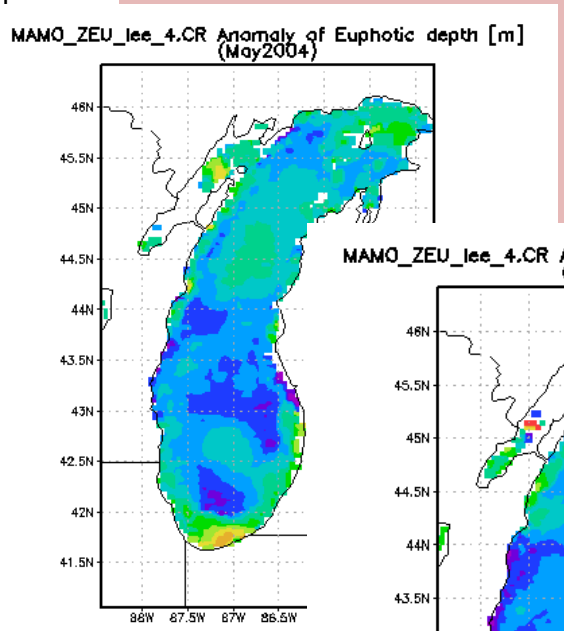
2003

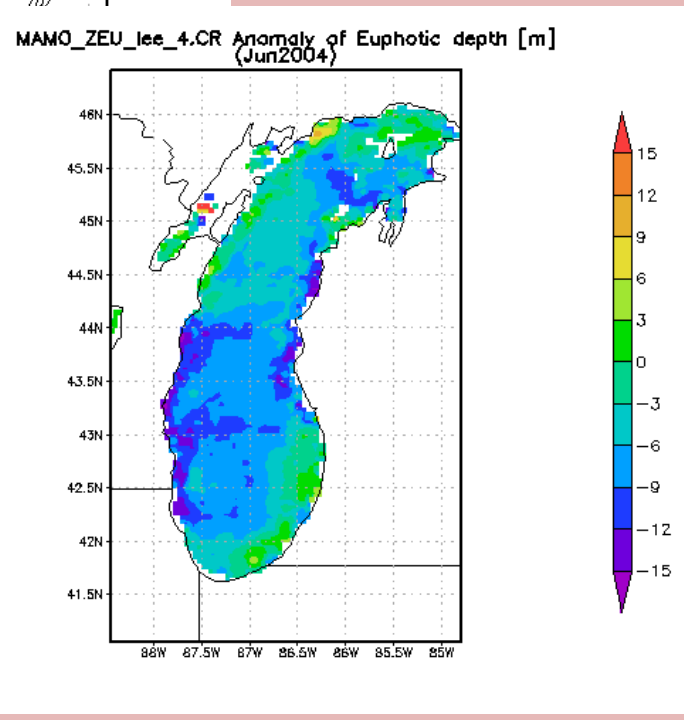
The classic pattern of the turbidity feature in the southern end of Lake Michigan is observed in 2003.

2004

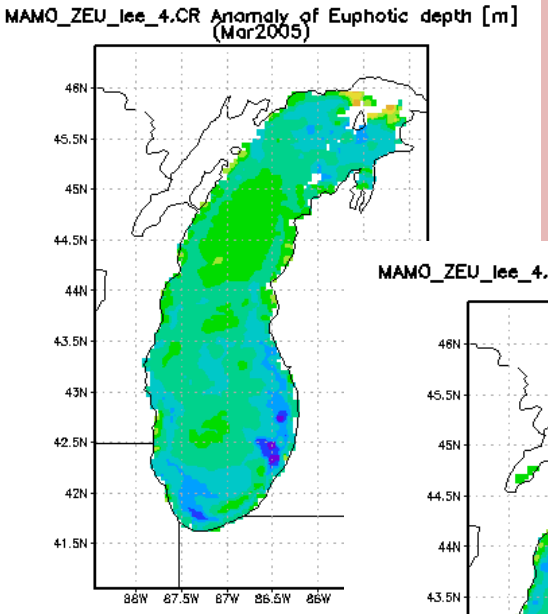


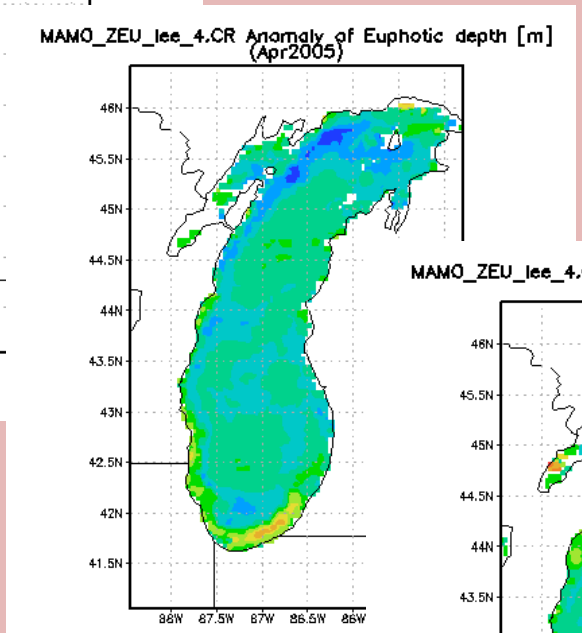


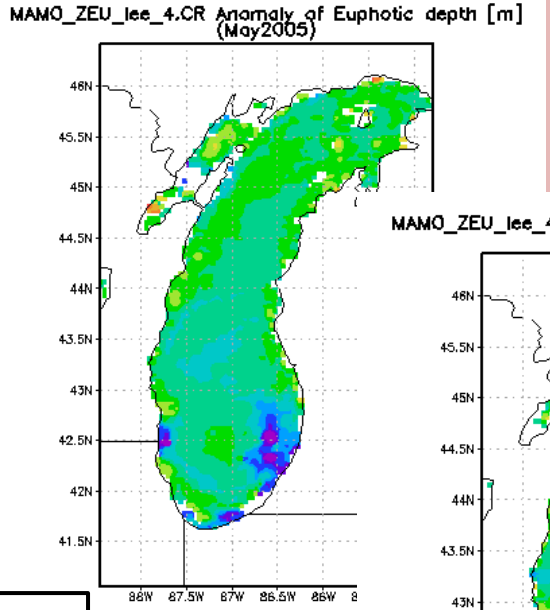


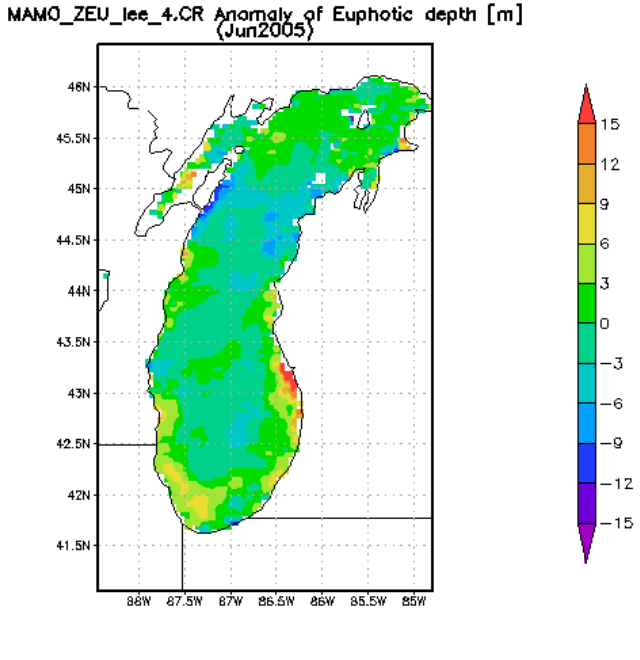


Turbidity is again present in 2004. In June, it covers a large area of the lake, more likely to be a spring phytoplankton bloom, or due to runoff from increased rainfall.



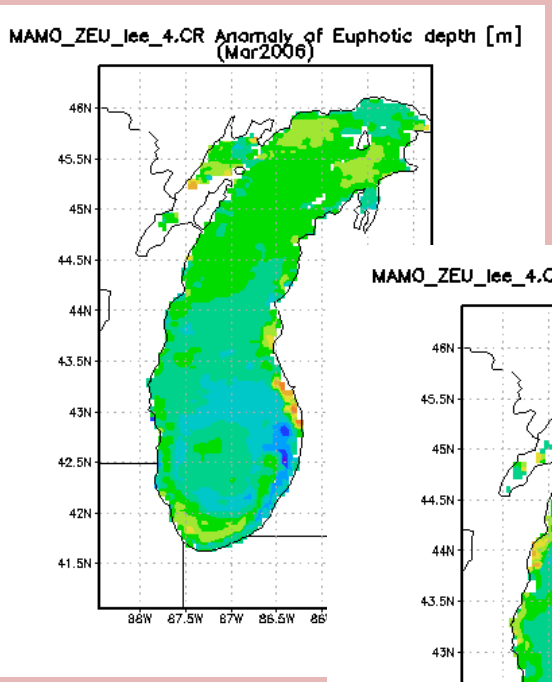


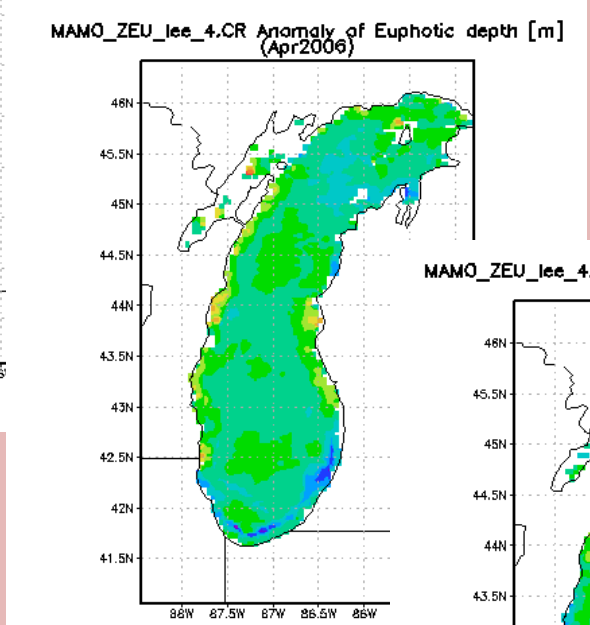


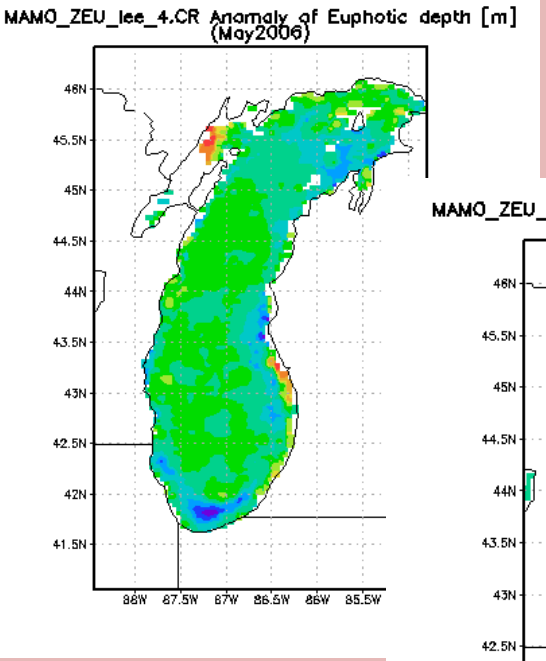


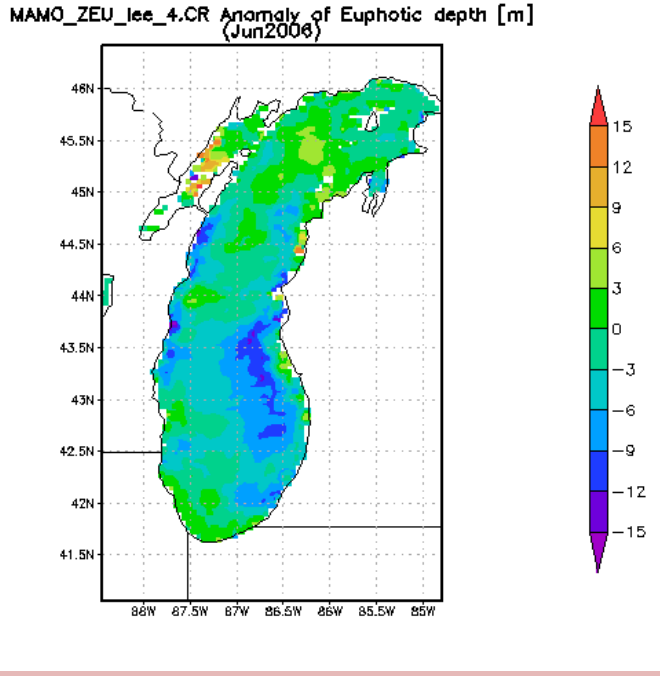
2005

The turbidity feature only appears weakly in the southern end of Lake Michigan in May 2005, with clearer water than average in April.



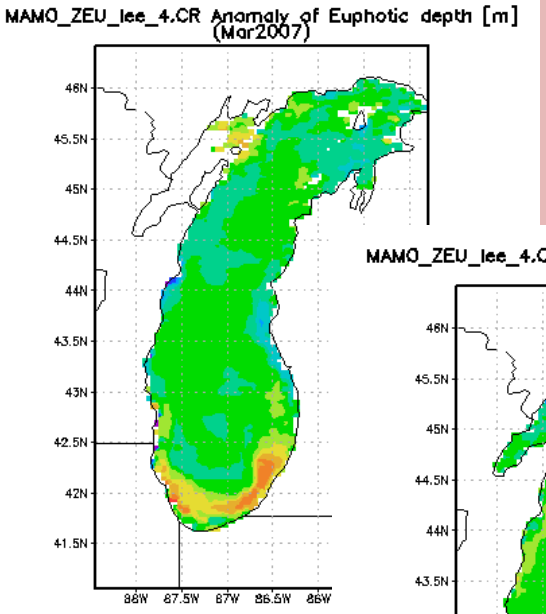


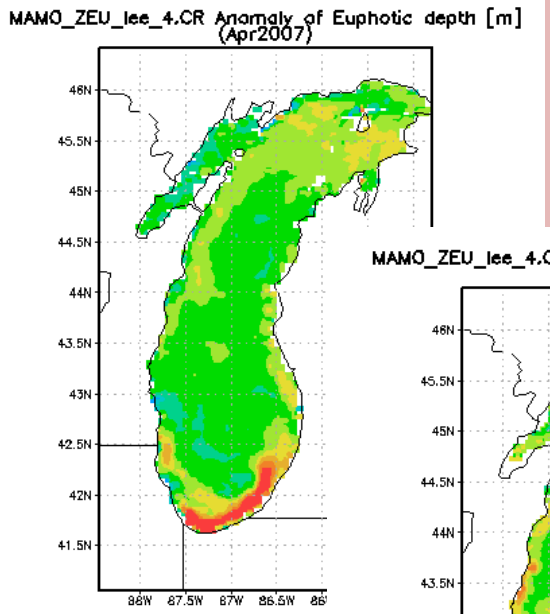


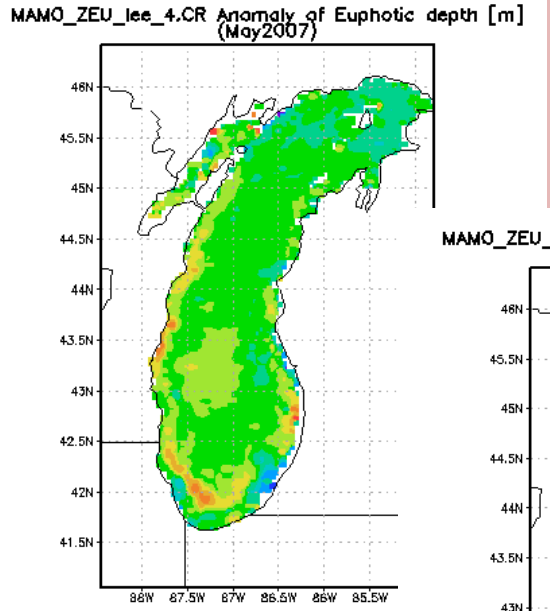


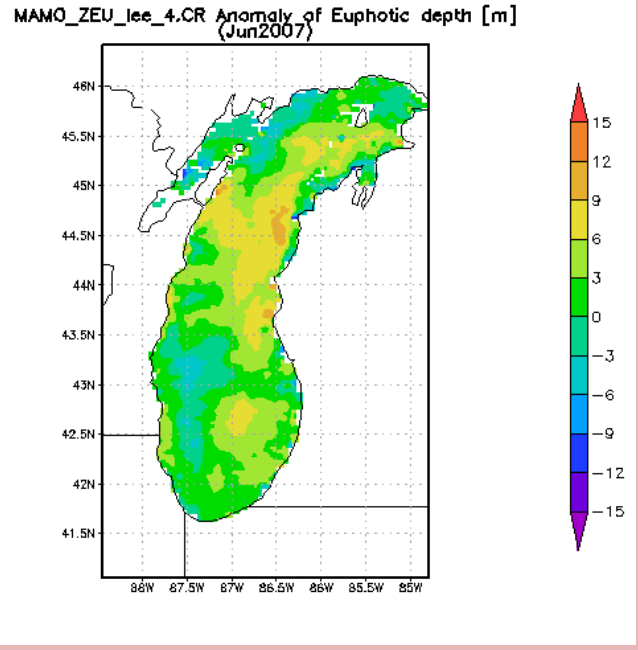
2006

Weaker and less prominent euphotic depth anomalies in the southern end of the lake occurred in 2006.





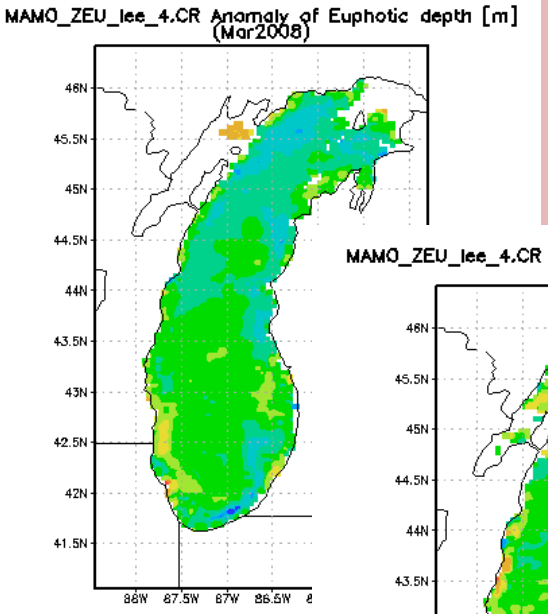


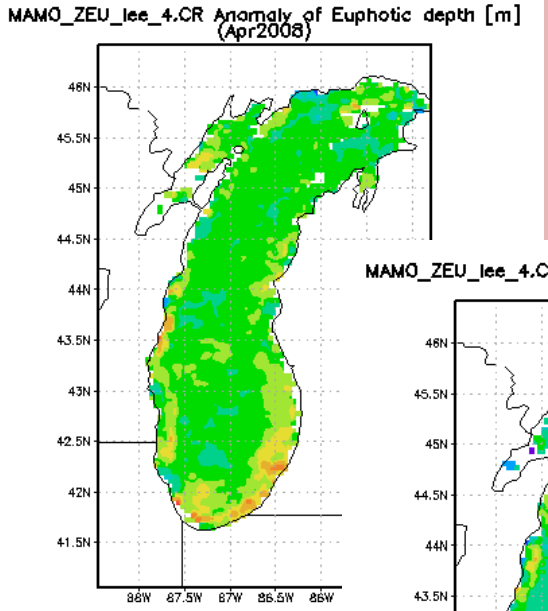


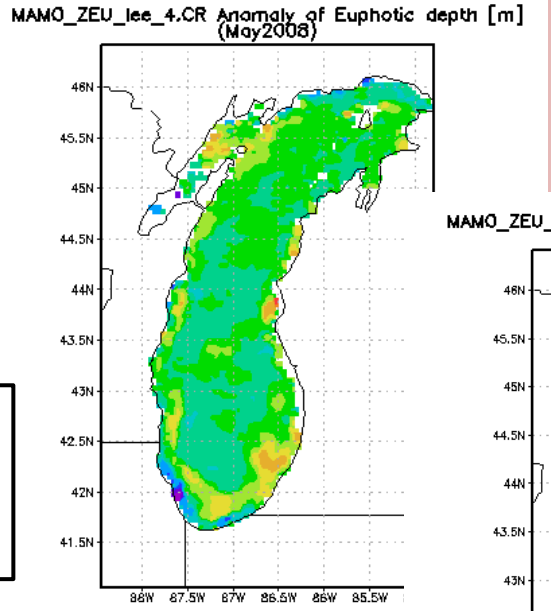
2007

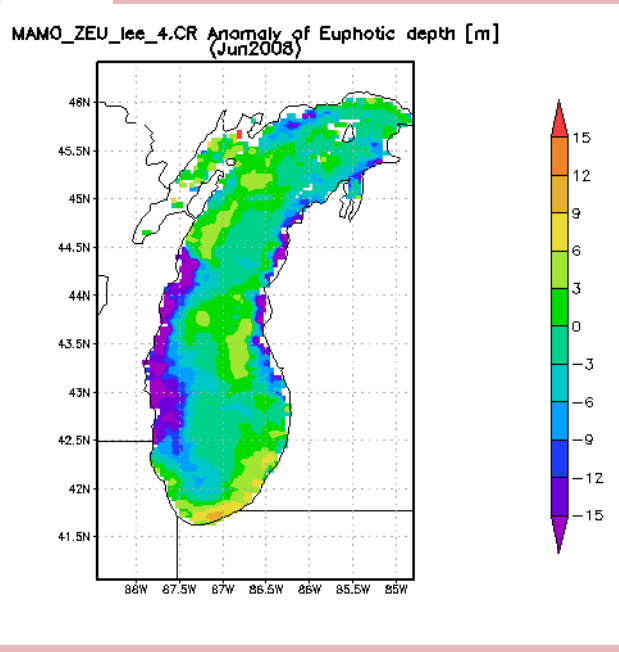
The turbidity feature was entirely absent in 2007. Water along the southern coast was much clearer than average (positive anomaly).

2008



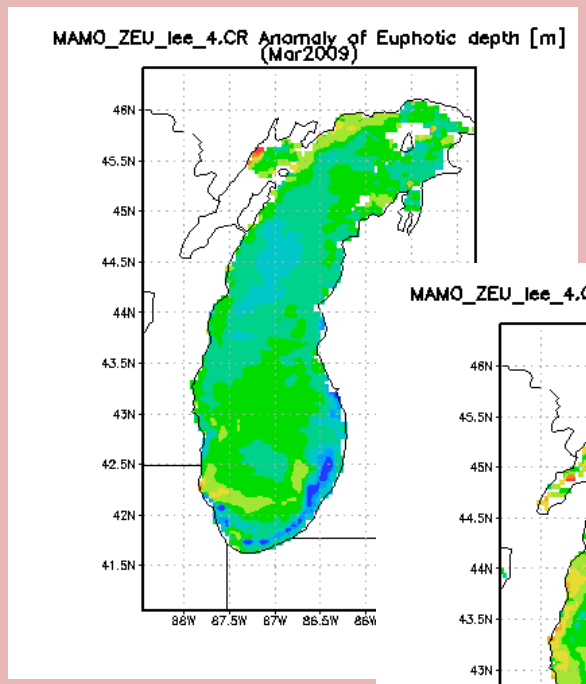


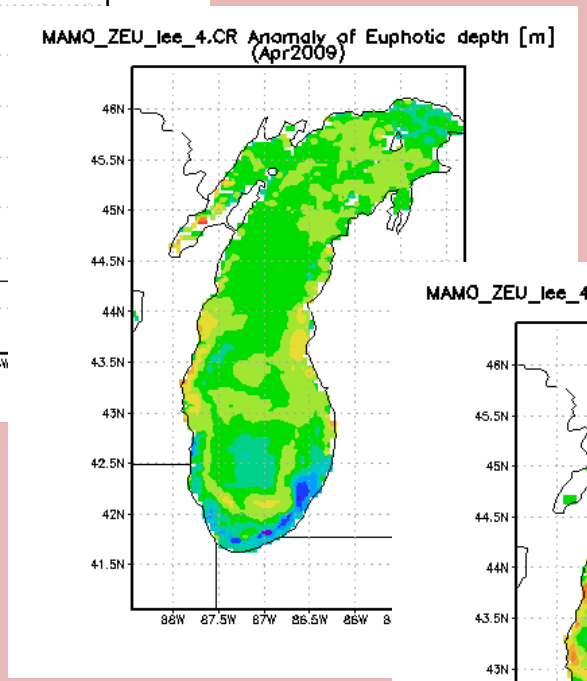


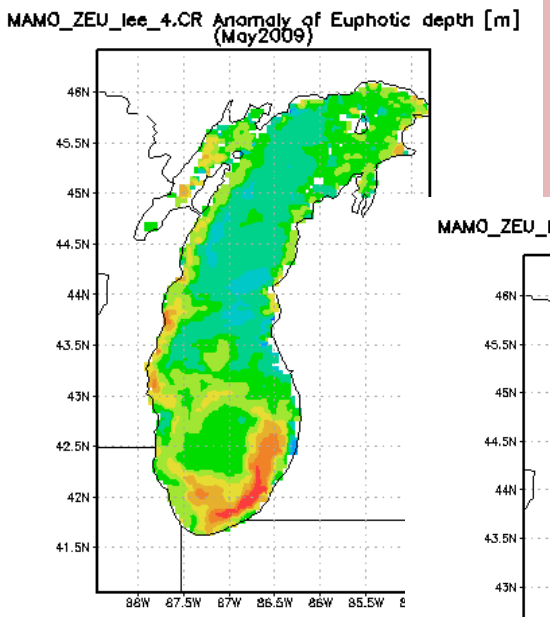


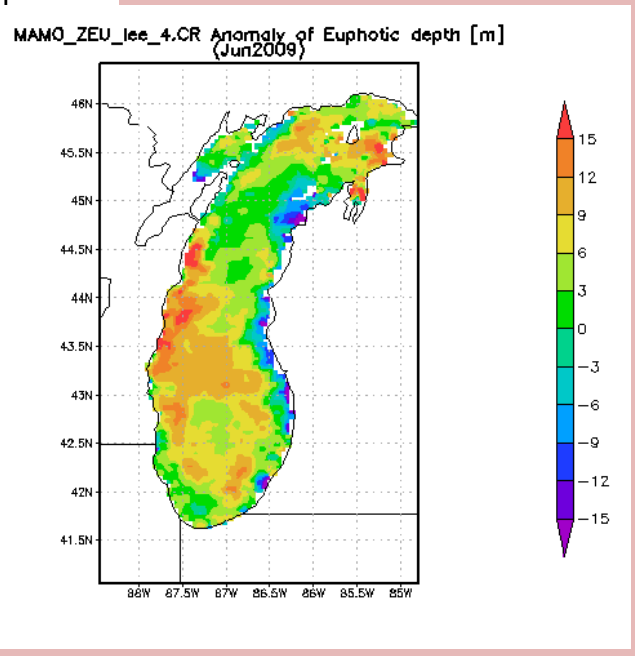
Elevated turbidity was not apparent in the southern end of Lake Michigan in 2008.

June 2008 shows a markedly different pattern. This turbidity was due to heavy rains, which famously flooded areas of the Midwest, including Des Moines, Iowa, threatening the pre-Olympic training of eventual gold medalist Shawn Johnson.



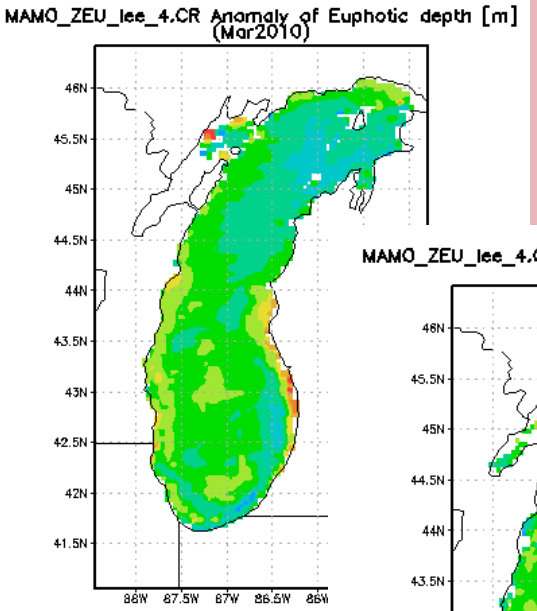


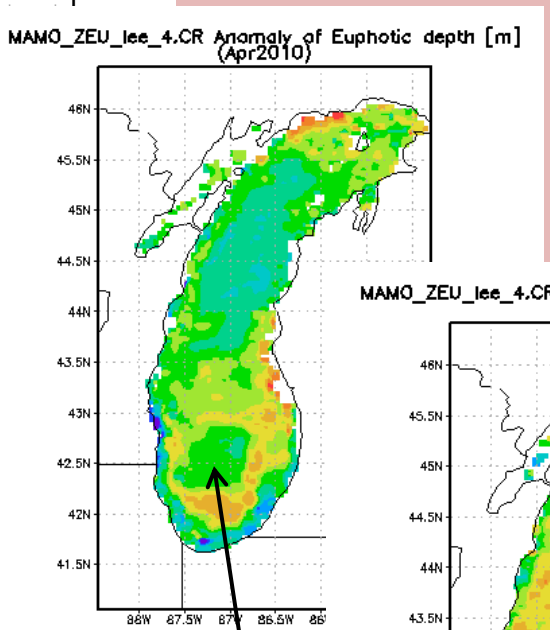


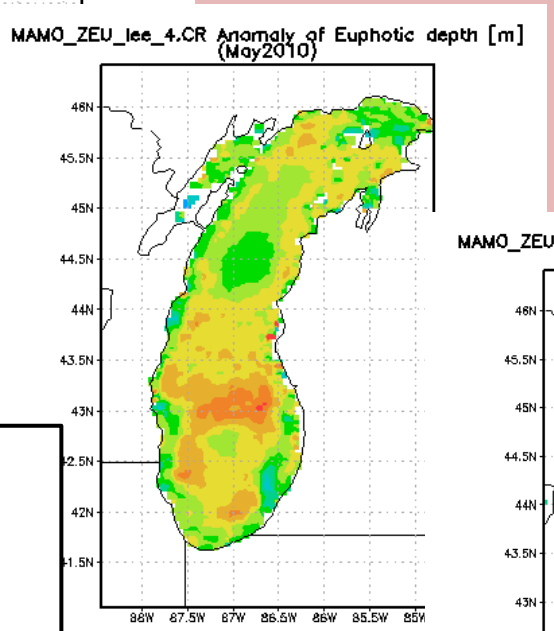


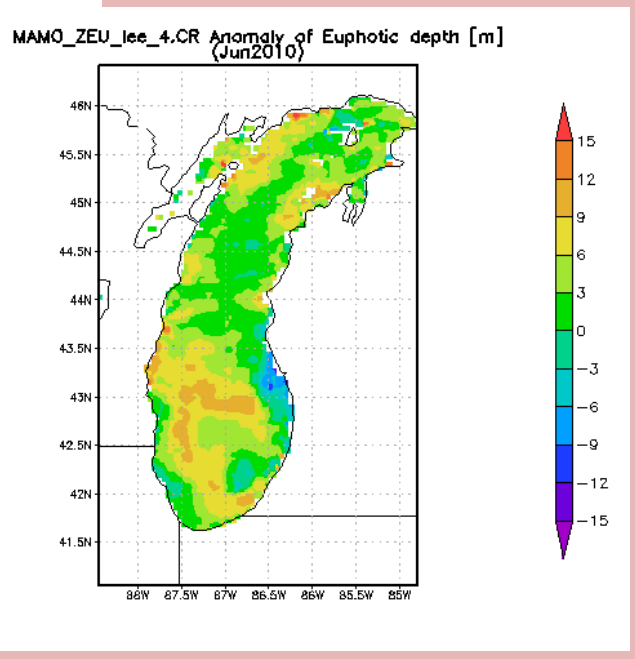
2009

Turbidity in the southern end of Lake Michigan was evident in March and April 2009, but much clearer water was observed in May and June.







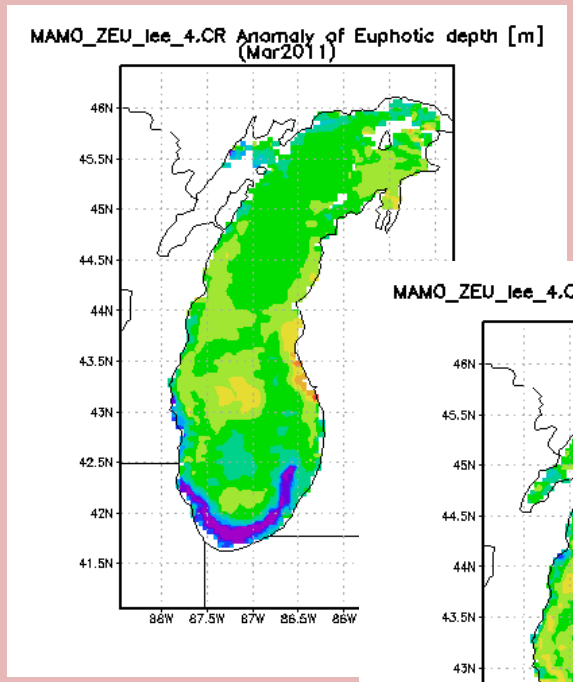


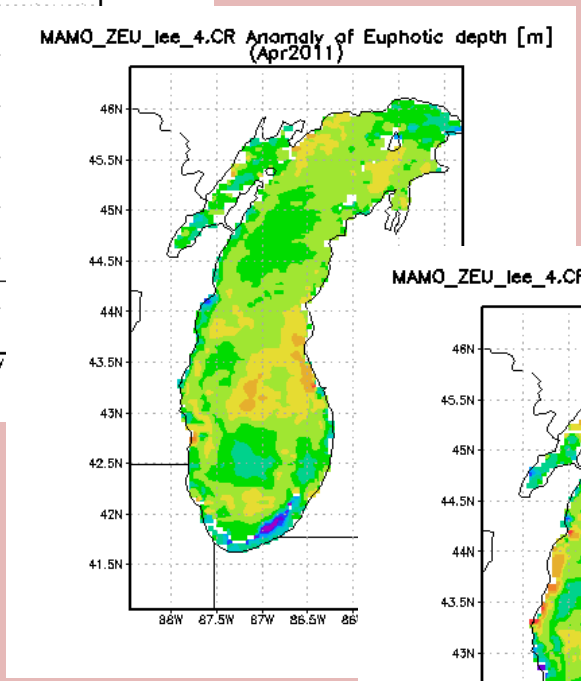
2010

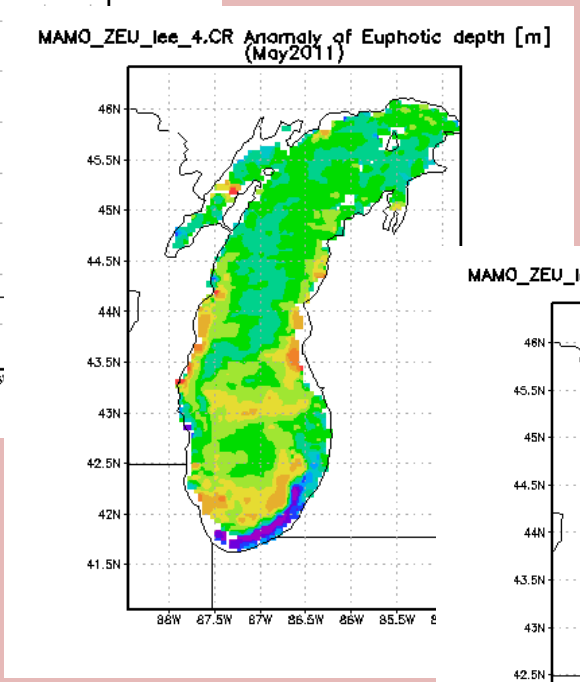
Slightly elevated turbidity occurs Just along the coast in 2010.

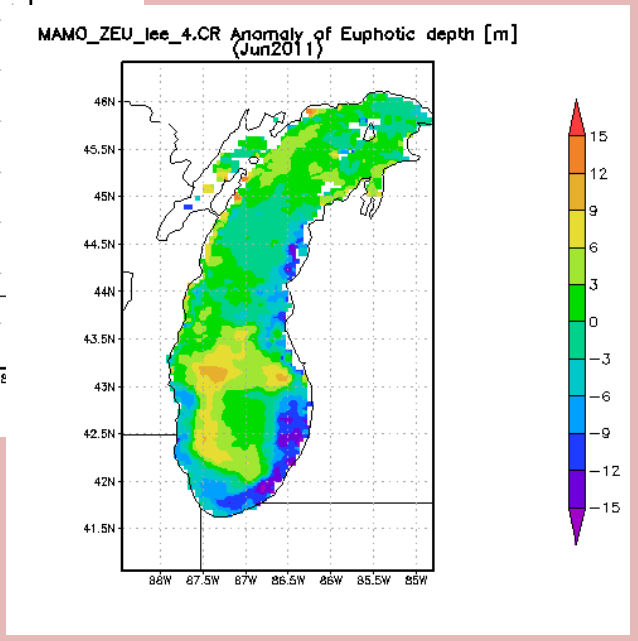
The “ring” pattern of the positive anomaly indicates that the dominant pattern of the euphotic depth anomaly was absent during this spring.

2011

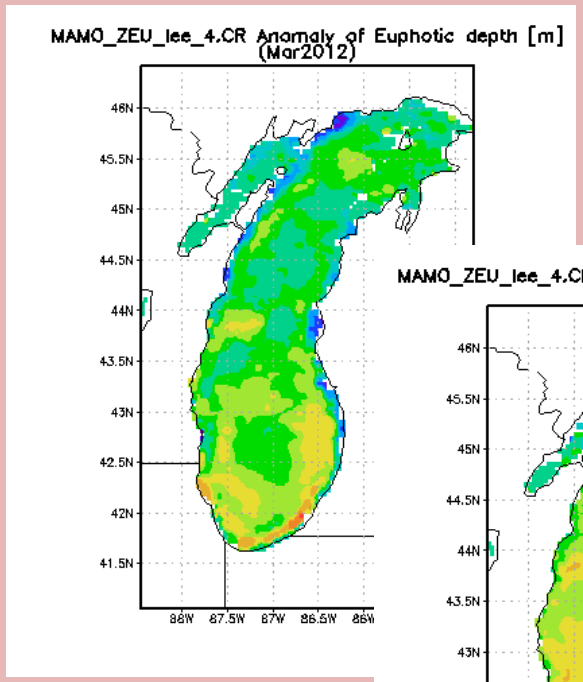


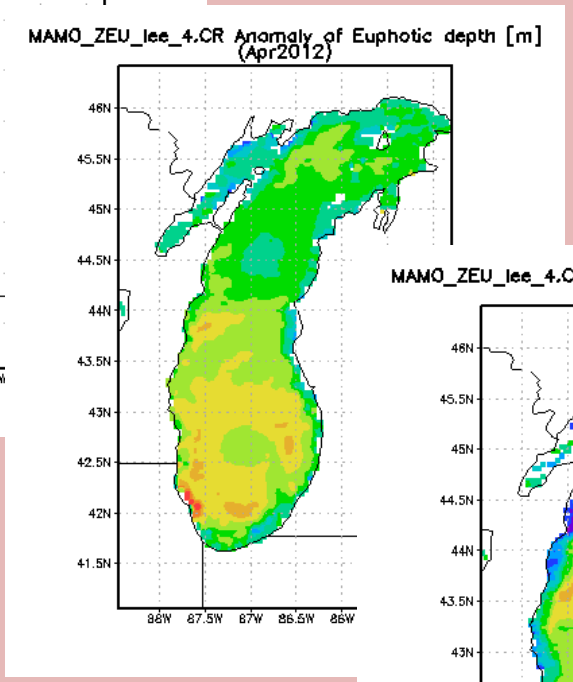


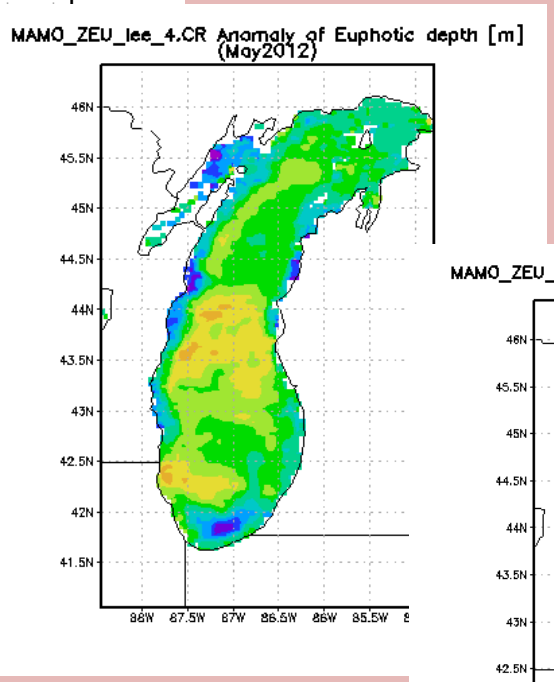


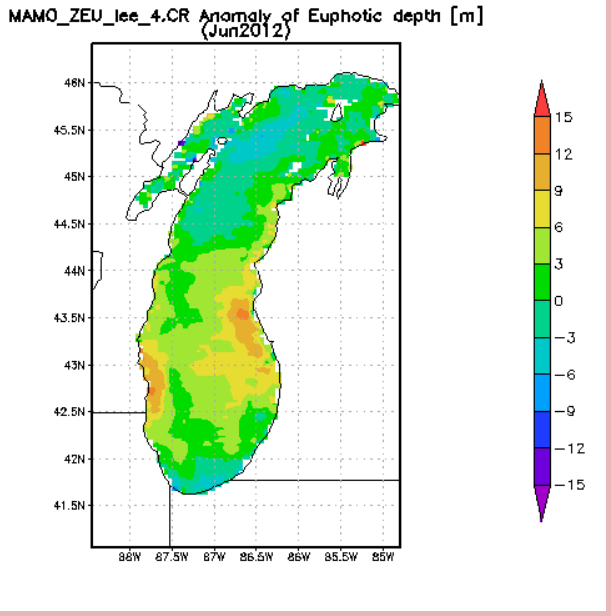


A return to the “classic” pattern occurred in spring 2011, though not as strongly as in 1998-2003.





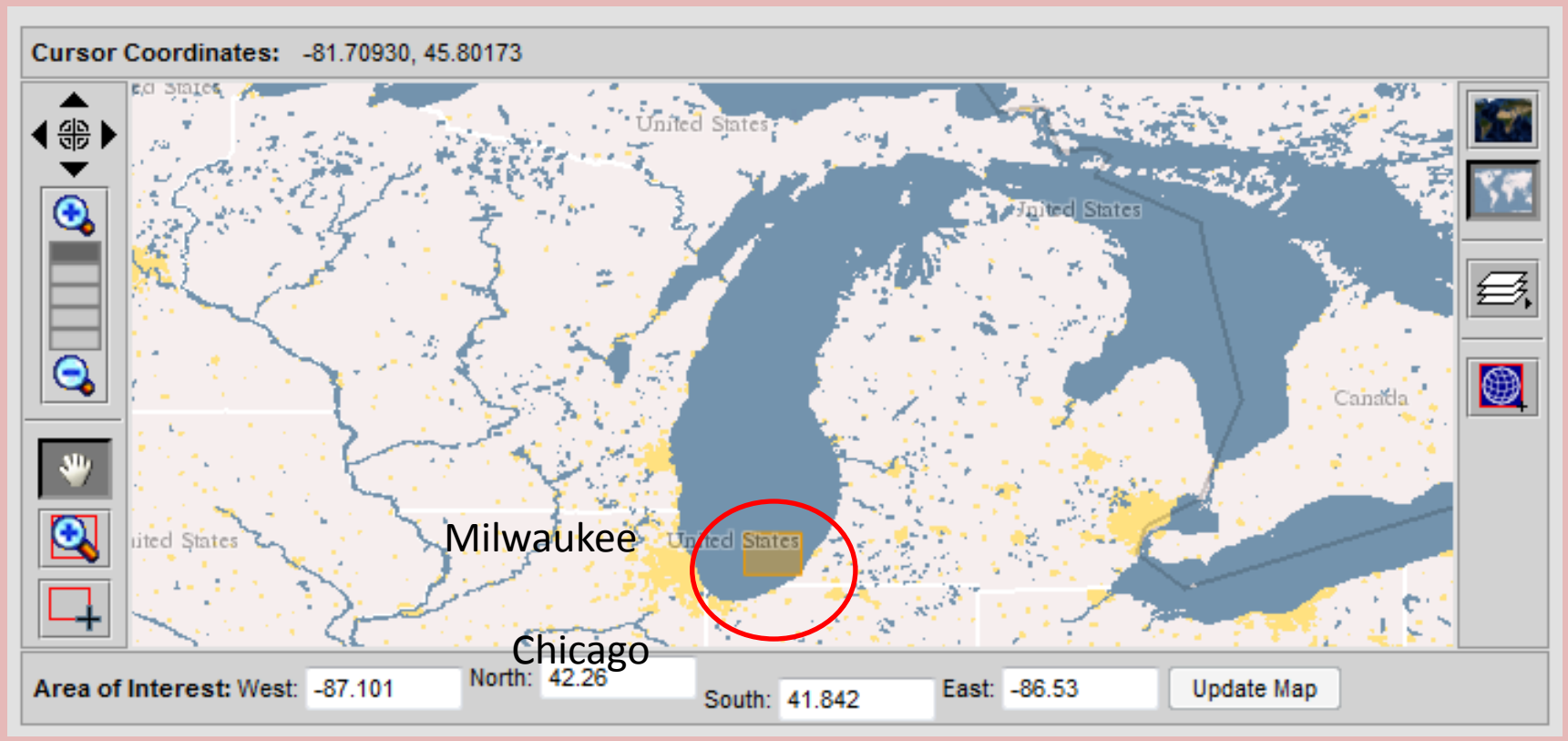




2012

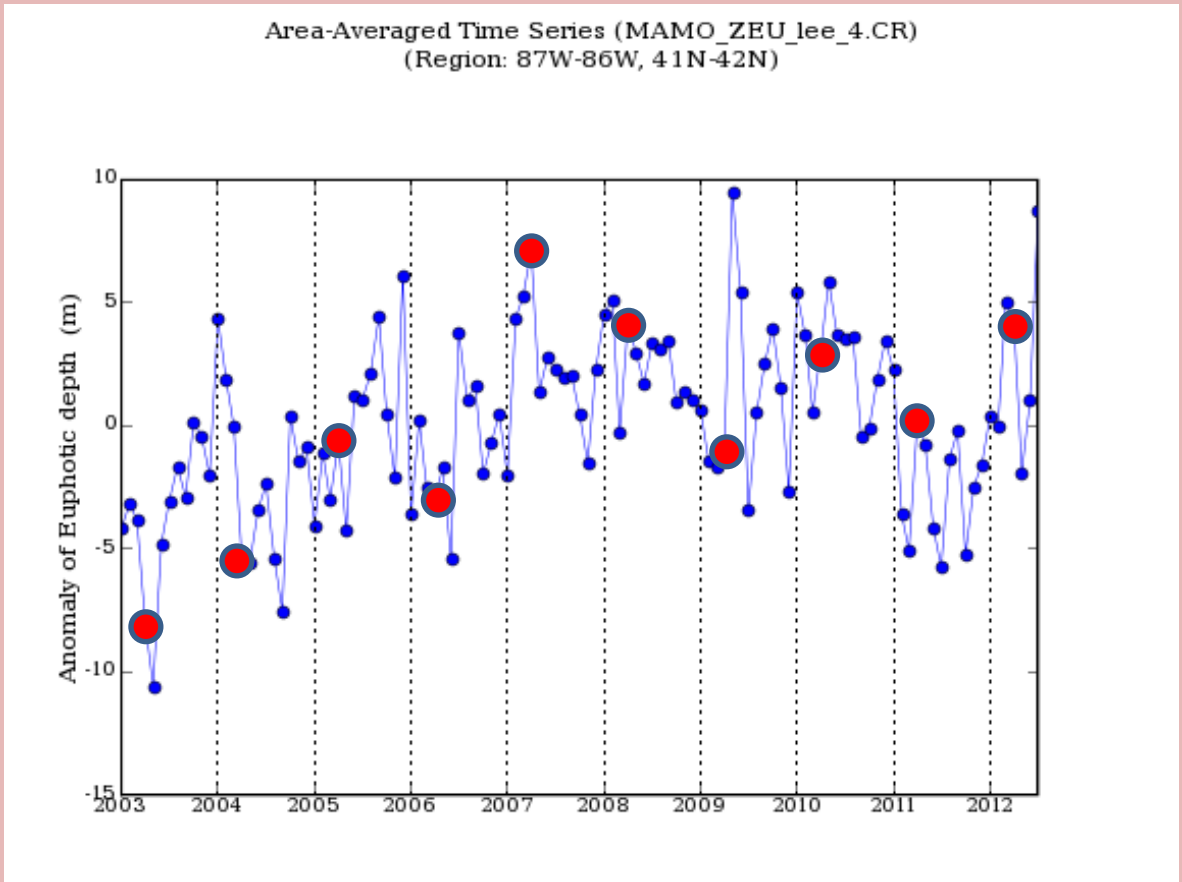
In 2012, the negative euphotic depth anomaly is again observed only in May.

“Warren Dunes” Study Area for Euphotic Depth Anomaly Time-Series



The square area in the southern end of the lake was selected for the generation of a euphotic depth anomaly time series, because it is in the zone where elevated coastal turbidity has been observed. It is offshore of Warren Dunes State Park in Michigan.

"Warren Dunes" Euphotic Depth Anomaly Time-Series



The dots in red indicate April, to allow easier visualization of the spring season.

A spring turbidity anomaly appears to have become a less characteristic feature of the annual cycle of Lake Michigan water clarity.

Also, because negative euphotic depth anomalies dominate the early years of this time series, overall Lake Michigan water clarity appears to have increased in this coastal area.

Summary

Examination of ten years of euphotic depth anomalies in Lake Michigan during the months of March-June indicates the following:

- The well-known and frequently observed occurrence of a turbidity feature in the southern part of Lake Michigan during the spring season has become less common during the period 2003-2012.

- Overall, the clarity of Lake Michigan water in the southern end of the lake appears to have increased spring season over the period 2003-2012.

- Euphotic depth can be used as a primary indicator of changes in Lake Michigan lacustrine optics, and for other large lakes.

- Unique events, such as the heavy rains in June 2008, can have a distinct signature in the euphotic depth anomaly distribution in Lake Michigan.